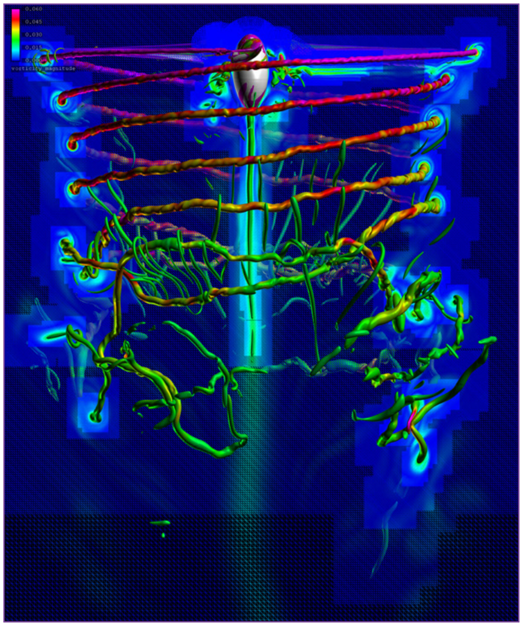
High-Resolution Navier-Stokes Simulation of Rotorcraft Wakes

Aeronautics Research Mission Directorate

Helicopters and tiltrotor aircraft provide crucial services such as emergency evacuation, security patrols, and military operations. High-fidelity, physics-based simulations provide valuable insight into the complex aero-mechanics and vortex phenomena involved in rotorcraft flight, helping engineers to reduce noise pollution and increase performance and heavy-lift capabilities in rotorcraft designs.

In support of NASA's Subsonic Rotary Wing Project, we are developing high-resolution computational fluid dynamics (CFD) simulation tools for rotorcraft applications. Using the OVERFLOW 2.2 CFD code, we have made several advancements in rotor wake simulation accuracy, including: use of 5th-order spatial accuracy for the Navier-Stokes equations to preserve vortex strength and reduce vortex diffusion in the flowfield; refinement of rotor blade surface resolution to improve predicted tip vortex strengths; and automated grid adaption to improve the resolution of wake vortices. With these techniques, we have been able to reduce vortex diameter error from 700% to 25%, and have improved prediction of the Figure of Merit for a hovering rotor (a measure of thrust and torque) to within 0.1% of the experimental value.



These high-resolution rotorcraft simulations require world-class supercomputing resources. A typical solution requires 35–500 million grid points, 256–4,096 processor cores, and two or more weeks of continuous computation. NASA's supercomputers and visualization capabilities enable verification and validation of these powerful computational tools, and provide new insight into the complex nature of rotor wakes.

Neal Chaderjian, NASA Ames Research Center
neal.chaderjian@nasa.gov

Navier-Stokes simulation of an isolated V-22 Osprey rotor in hover. Vortices are rendered with isosurfaces based on the Q-criterion. Two levels of grid adaption improve rotor vortex resolution and predict the Figure of Merit within experimental accuracy. Magenta is high vorticity and blue is low vorticity. *Neal Chaderjian, Timothy Sandstrom, NASA/Ames*